Cycle-4 STOP and Jitter Integrated Modeling (IM) "First Look" (partial and preliminary; un-optimized)

Cliff Jackson and IM Team

July 29, 2014

Cycle-4 Integrated Modeling (IM) Team!

- Optical Models (WIM, WSM, and CGI)
  - Bert Pasquale, Hong Tang, Patrick Thompson
- Linear Optical Models (LOM)
  - Joe Howard
- Structural Design/Model/Analysis
  - Cory Powell, Zensheu Chang, Andrew Jabola, Séké Godo, Miguel Polanco, Nerses Armani, Tom Wallace … both static and dynamic
- Thermal Design/Model/Analysis
  - Hume Peabody (Carson McDonald), Hung Pham, Juan Villalvazo
- Structural/Thermal Mapping
  - Hume Peabody (Thermal Desktop)
  - Séké Godo (Nastran Thermal Analyzer linear interpolations)
- LOM-based WFE/LOS/PSF Model/Analysis (STOP and Jitter)
  - Carl Blaurock, Alice Liu
  - Includes all vibration disturbance inputs
- Sigfit-based Cooldown/Orbital WFE/LOS Model/Analysis (STOP)
  - Martina Atanassova

Overview of Cycle-4 Integrated Modeling

- Design Freeze ~April 1 (excepting Grism)
  - WF Grism and Coronagraph optical paths added to WF Imaging
  - New on-axis telescope optical design
  - WF Channel non-rectangular and non-planar focal plane
  - WF Channel mirror mounts much more athermalized (enables near optimal refocus with T2/F2 despace following cooldown)
  - Cryocooler cools WF and IFU Channel SCAs/SCEs <=90K
  - WFI electronics moved from S/C to WFI Housing (servicing driven)
  - CoronaGraph Instrument (CGI) 0.4° off-axis and fed by two periscope relay mirrors on Carrier
  - Carrier with A/B/C latches ~in-plane (not 3-D truss)
- Modeling Freeze ~End of May (excepting Grism)
- STOP and Jitter Loading/Analysis Phase June/July

Cycle-4 Model Configurations … Only Two

- **WIM/CGI Model Configuration**
  - "WIM" = Widefield Imaging Mode, which has the Widefield Channel Element Wheel set to locate a filter in the beam path.
    - LOS and WFE performance is assessed at one of 19 field point positions at the Widefield Channel's focal plane (center field point, #19, results shown)
    - Optical Path is T1/T2/F1/M3/Filter-Surface-1/Filter-Surface-2/F2/FPA
  - "CGI" = CoronaGraph Instrument
    - LOS/WFE performance is assessed at the center of the CGI's first internal Focus
    - Optical Path is T1/T2/Carrier Relay #1/Carrier Relay #2, followed by 7 optical elements internal to the CGI, including its first internal focus.
    - All CGI mirrors are points … rigid body motions are assessed, no deformations
- **WSM/CGI Model Configuration**
  - "WSM" = Widefield Spectroscopy Mode, which uses the Element Wheel to place a Grism in the Widefield Channel's beam path instead of a filter.
  - Otherwise, identical to WIM/CGI Configuration

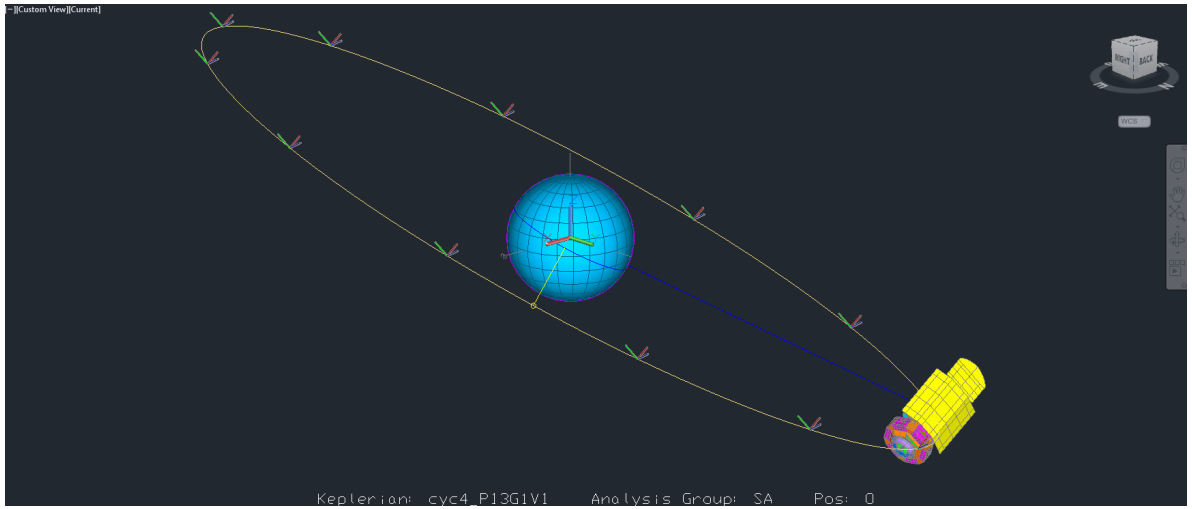
For STOP: First of Two Cycle-4 Orbit/Attitude Cases

- **WF Channel Worst Slew Case:** (mod of Cyc-3 worst slew case)
  - Observatory stabilized in Hot Case condition pitched away from the Sun, and LOS/WFE stability assessed after instantaneous slew to Cold Case condition pitched towards the Sun
  - Pitch extended from ±33.5° (Cyc-3) to ±36° (Cyc-4)
  - Roll changed from zero (Cyc-3) to worst of ±15° (Cyc-4)
  - Cases documented, including an orbit update enabled by the use of the Cryocooler (WFI radiator normals can be in orbit plane), in Chris Hirata's "Thermal Limits_v5"
  - I

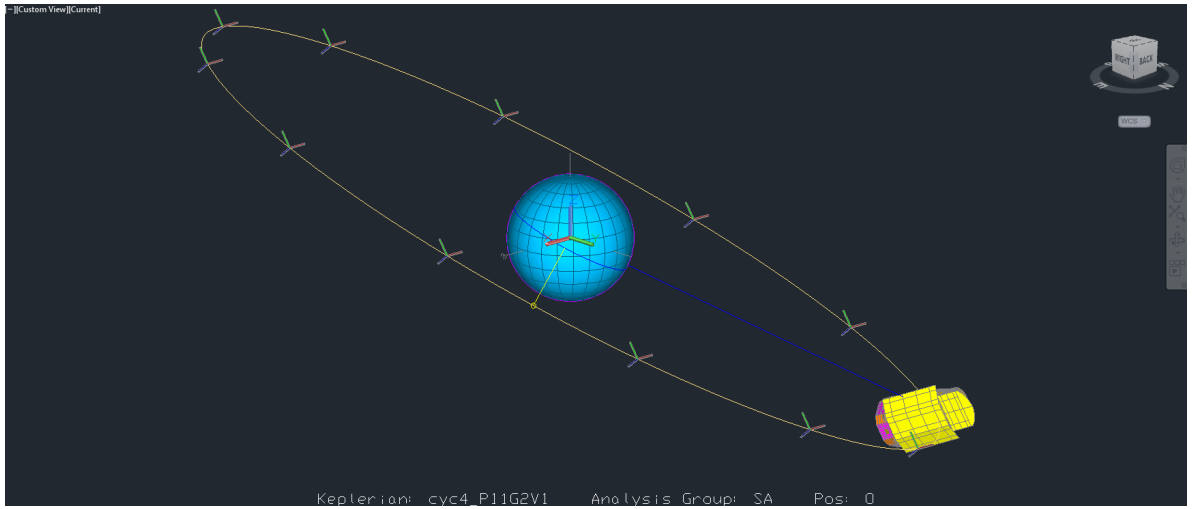
All angles in degrees

Label	Pitch P	Roll ρ	Azimuth A	Azimuth θ_Z	LOS RA	LOS Dec	$PA_{sunshade}$	γ_{LOS}	γ_{rad}
				$\beta = 11°$ cases					
C01B11P13G1V1	36.00	15.00	55.84	258.66	191.85	24.47	302.66	41.80	0.00
C01B11P11G2V1	-36.00	15.00	90.36	224.14	104.25	22.50	260.83	41.70	48.11

WF Channel Worst Slew Case



- Hot Attitude
- P13G1V1 from "Thermal Limits_v5"



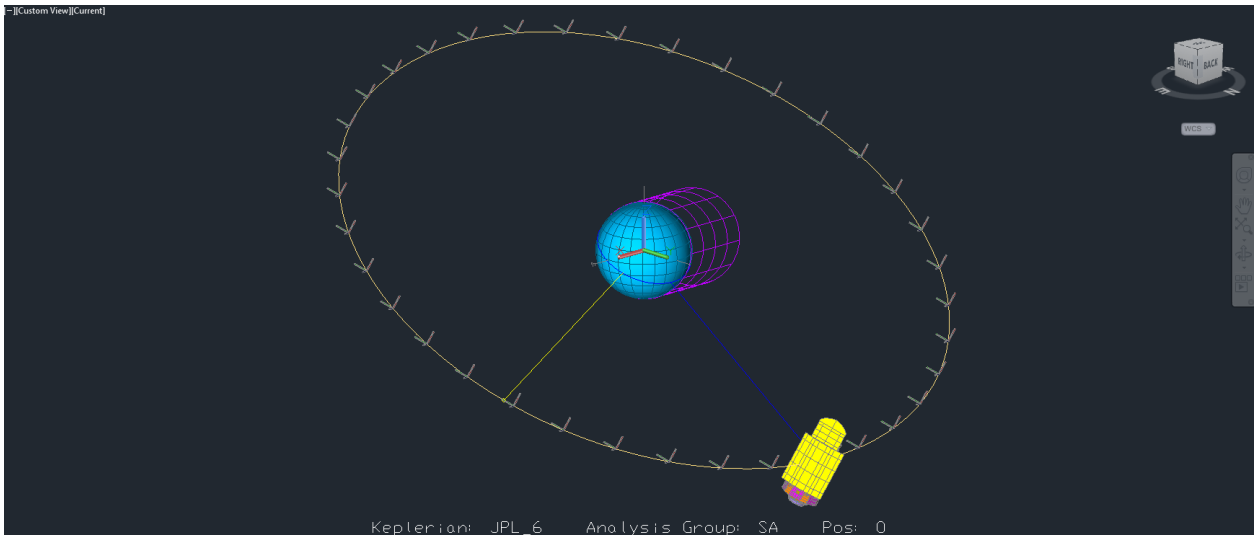
- Cold Attitude
- P11G2V1 from "Thermal Limits_v5"

For STOP: Second of Two Cycle-4 Orbit/Attitude Cases

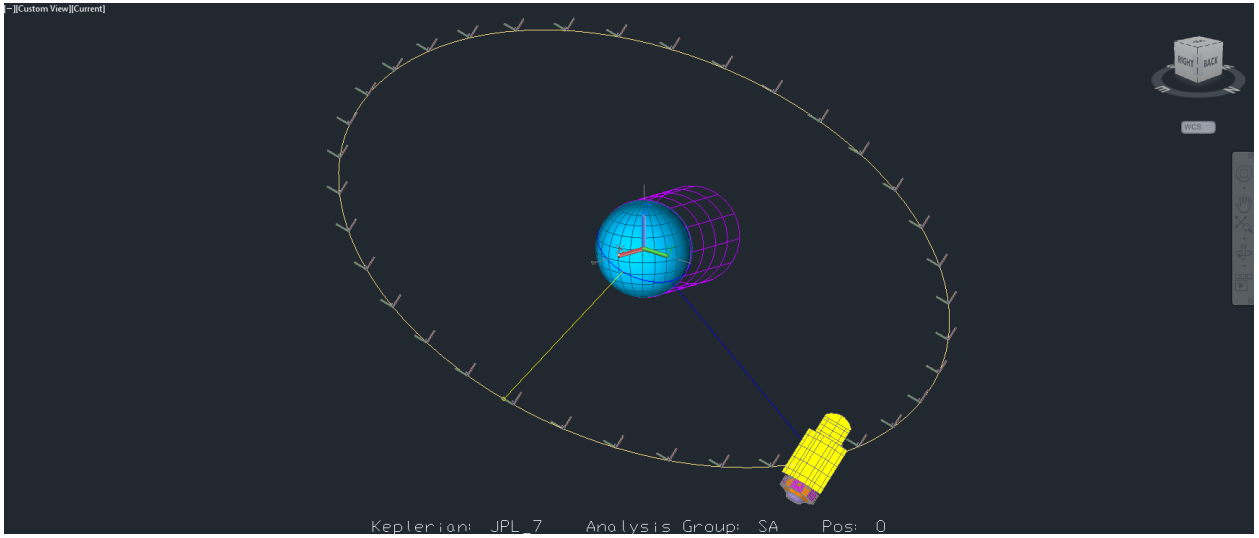
- **CGI Representative Slew Case**
  - Observatory stabilized with Telescope LOS 62° off GEO orbit plane
    - Reduces Earth thermal flux input variations into the Telescope aperture
  - Slew instantaneously to attitude with Telescope LOS 42° off GEO orbit plane. This angle is as close to the GEO orbit plane as the telescope can point without allowing Earth thermal flux to strike T1 at some point in the orbit.
  - Case documented in Thermal Desktop orbit/attitude definition provided by CGI team, and an Excel spread sheet, below:

Case	Beta	Pitch (rot_Y)	Roll (rot_X)	Yaw (rot_Z)	Resulting γLOS	Comment
JPL-6	28	0	0	-90	62	
JPL-7 (new)	28	20	0	-90	42	For Coronagraph transient: JPL-6 steady state + 4 orbits of JPL-7

CGI Representative Slew Case



- Telescope LOS 62° out of GEO orbit plane
- Case 6 from CGI Excel Orbits Table



- Telescope LOS 42° out of GEO orbit plane
- Case 7 from CGI Excel Orbits Table

For Jitter: Two Primary Cycle-4 Disturbance Cases

- **Reaction Wheel Assembly (RWA) disturbances** were applied independently at each of 4 RWAs
  - No change to RWA input disturbances from Cyc-3
  - Response vs frequency for worst wheel is shown
  - Standard wheels only (fine balance improves fundamental ~x2)
  - RWA isolators physically modeled in Cyc-4
- **Cryocooler disturbances** were applied independently at WideField and IFU Channel FPA heat exchangers and at Cooler Compressor to assess impact
  - No change to Cooler input disturbance spectrum shown at April 2014 SDT Meeting

IM Analyses In Process … STOP Status Matrix Below

Configuration	Thermal Load Case	LOM Assessment	Sigfit Assessment
WIM/CGI STOP	WF Worst Slew	WIM* Orbital Δ	(WIM* Orbital Δ)
"	"	(WIM* Cooldown)	WIM* Cooldown
"	"	CGI* Orbital Δ	n/a
"	"	CGI* Cooldown	n/a
"	CGI Case 6/7 Slew**	CGI* Orbital Δ	n/a
"	"	CGI* Cooldown	n/a
WSM/CGI STOP	WF Worst Slew	WSM*** Orbital Δ	n/a
"	"	WSM*** Cooldown	n/a

Green Fill = Model or Analysis Results Available

* **WIM center field point #19 currently, will extend to span FPA; Only 1 field point exists for CGI … all Cyc-4 CGI mirrors are represented as points;**

** **One time step may be corrupted … checking;**

*** **WSM field point #19 currently at 1.65 um, will extend to span FPA, and cover 1.35 um and 1.95 um.**

IM Analyses In Process … Jitter* Status Matrix Below

Configuration	Vibration Load Case	LOM Assessment	Sigfit Assessment
WIM/CGI Dynamics	RWA #1 thru #4	WIM** Jitter	n/a
"	RWA #1 thru #4	CGI** Jitter	n/a
"	Cryocooler	WIM** Jitter	n/a
"	Cryocooler	CGI** Jitter	n/a
WSM/CGI Dynamics	RWA #1 thru #4	WSM*** Jitter	n/a
"	RWA #1 thru #4	CGI** Jitter	n/a
"	Cryocooler	WSM*** Jitter	n/a
"	Cryocooler	CGI** Jitter	n/a

Green Fill = Model or Analysis Results Available

* **No vibration-induced optical element deformations included in Jitter analysis;**

** **WIM center field point #19 currently, will extend to span FPA; Only 1 field point exists for CGI … all Cyc-4 CGI mirrors are represented as points;**

*** **WSM center field point #19 currently at 1.65 um, will extend to span FPA, and cover 1.35 um and 1.95 um.**

Cyc-4 IM Results Overview (WSM and CGI Slew in-process; Sigfit Cooldown Follows)

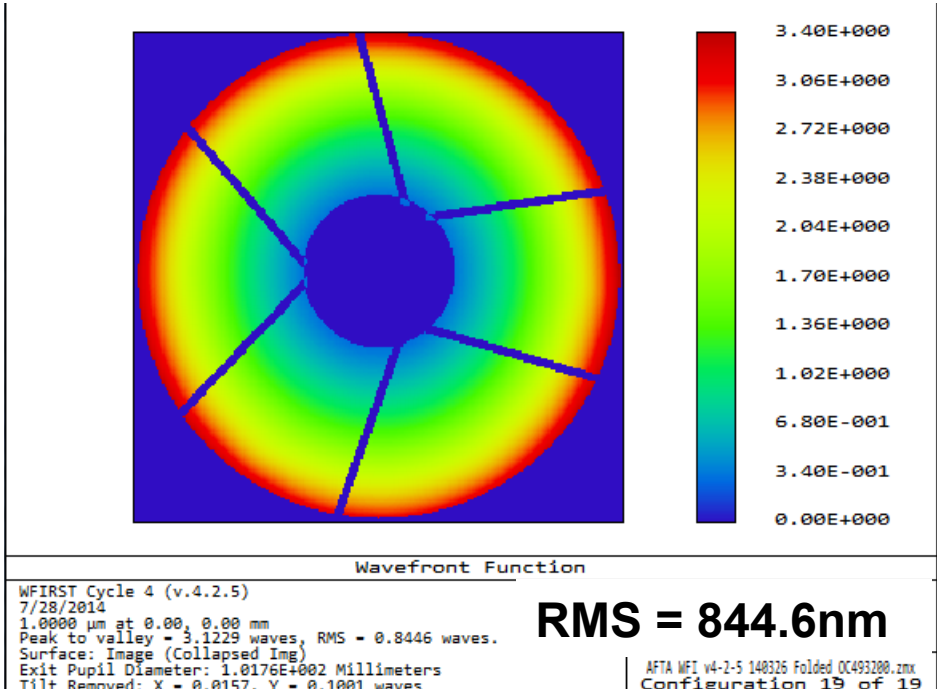
Parameter	Requirement	Disturbance	MUF*	Predict*	Margin
WIM WFE Drift	<0.707 nm/184s	WFI Worst Slew	x3	0.059 nm/ 184s	x12
WIM PSF Drift	<4.7e-4 / 184s	WFI Worst Slew	x3	8.3 e-6 nm/184s	x57
CGI WFE Drift	TBD	WFI Worst Slew	x3	pending	TBD
CGI LOS Drift	TBD	WFI Worst Slew	x3	pending	TBD
WIM LOS Jitter	14 mas rms/axis	RWA**	x2.5 to x5.85	5.93 mas-Y @ 46.53 Hz	x2.4
WIM WFE Jitter	0.707 nm rms	RWA**	x2.5 to x 5.85	0.148 nm @50.21 Hz	x4.8
CGI LOS Jitter	TBD	RWA	x2.5 to x5.85	5.86 mas-Y @ 46.53 Hz	TBD
CGI WFE Jitter	TBD	RWA	x2.5 to x5.85	pending	TBD
WIM LOS Jitter	14 mas rms/axis	Cooler**	x10.85 to 13.26	0.152 mas (X-rss)	x92
WIM WFE Jitter	0.707 nm rms	Cooler**	x10.85 to 13.26	0.0045 nm (rss)	x157
CGI LOS Jitter	TBD	Cooler	x10.85 to 13.26	0.127 mas (X-rss)	TBD
CGI WFE Jitter	TBD	Cooler	x10.85 to 13.26	pending	TBD

*** The MUF is <u>included</u> in all Predicts**

**** Technically need to sub-allocate Rqt to RWA and Cooler**

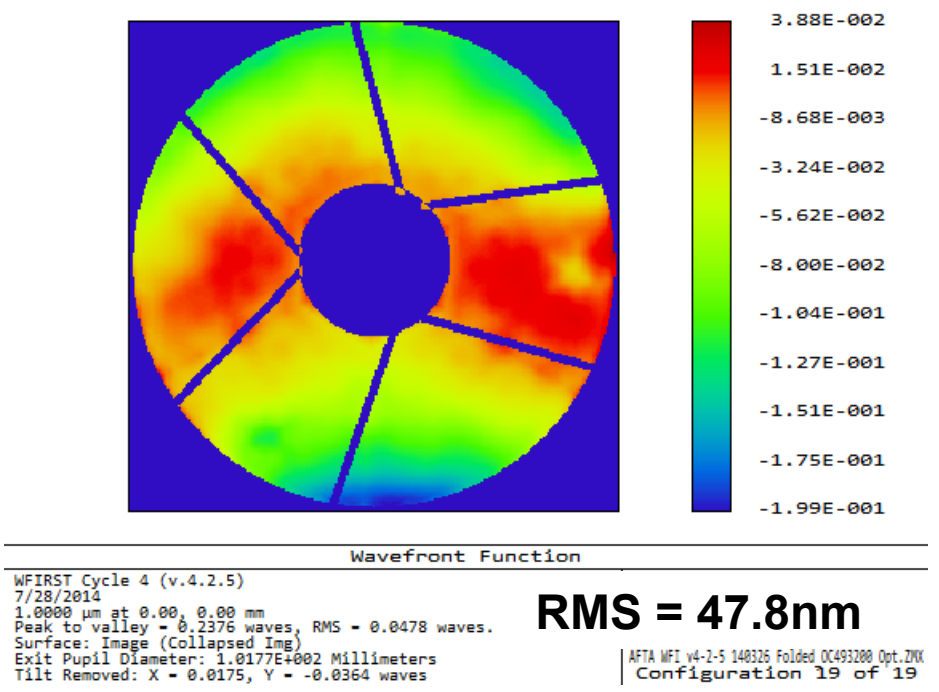
SigFit WIM Wavefront Map of Initial Cooldown Before and After Refocus with T2 and F2 de-space

Before Refocus



RMS = 844.6nm

After Refocus

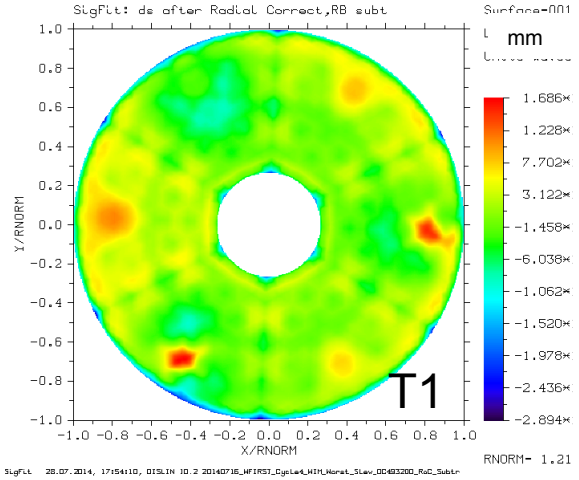


RMS = 47.8nm

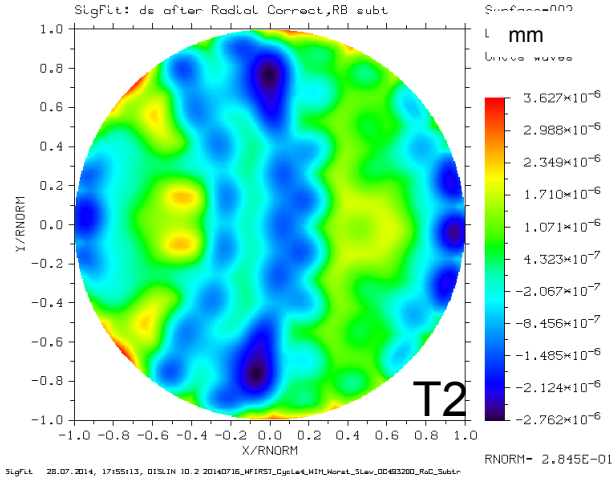
Baseline RMS = 33.2nm

<for single central field point … will expand to surrounding field points>

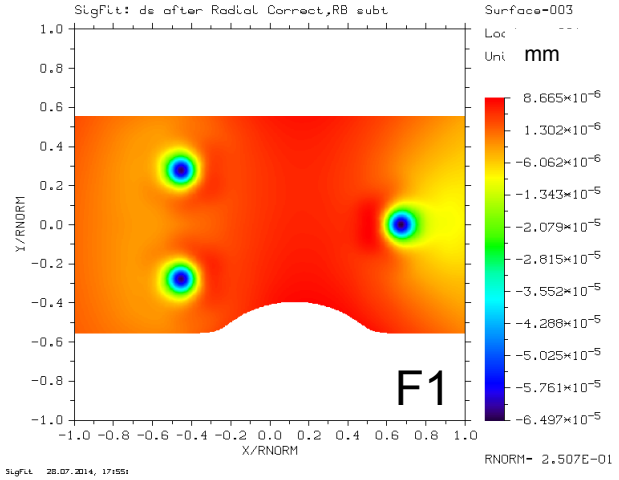
Surface Sags (RoC Subtracted* - higher order surface errors)



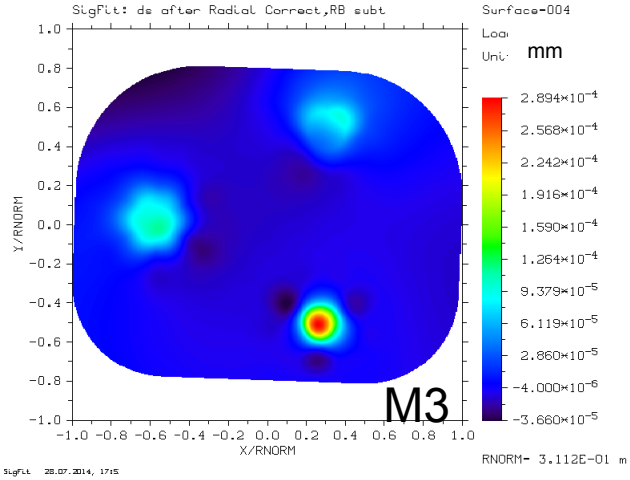
RMS = 4.5 nm
P-V = 49.9nm



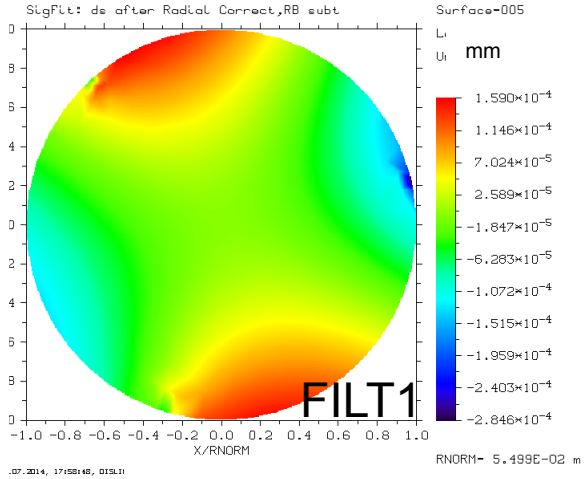
RMS = 1.1nm
P-V = 6.4nm



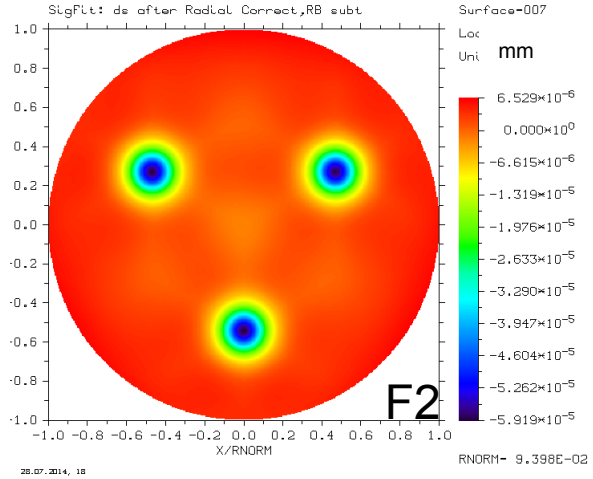
RMS = 8.3 nm
P-V = 73.7 nm



RMS = 29.6 nm
P-V = 326.2 nm



RMS = 63.9 nm
P-V = 445.4 nm



RMS = 8.7 nm
P-V = 65.8 nm

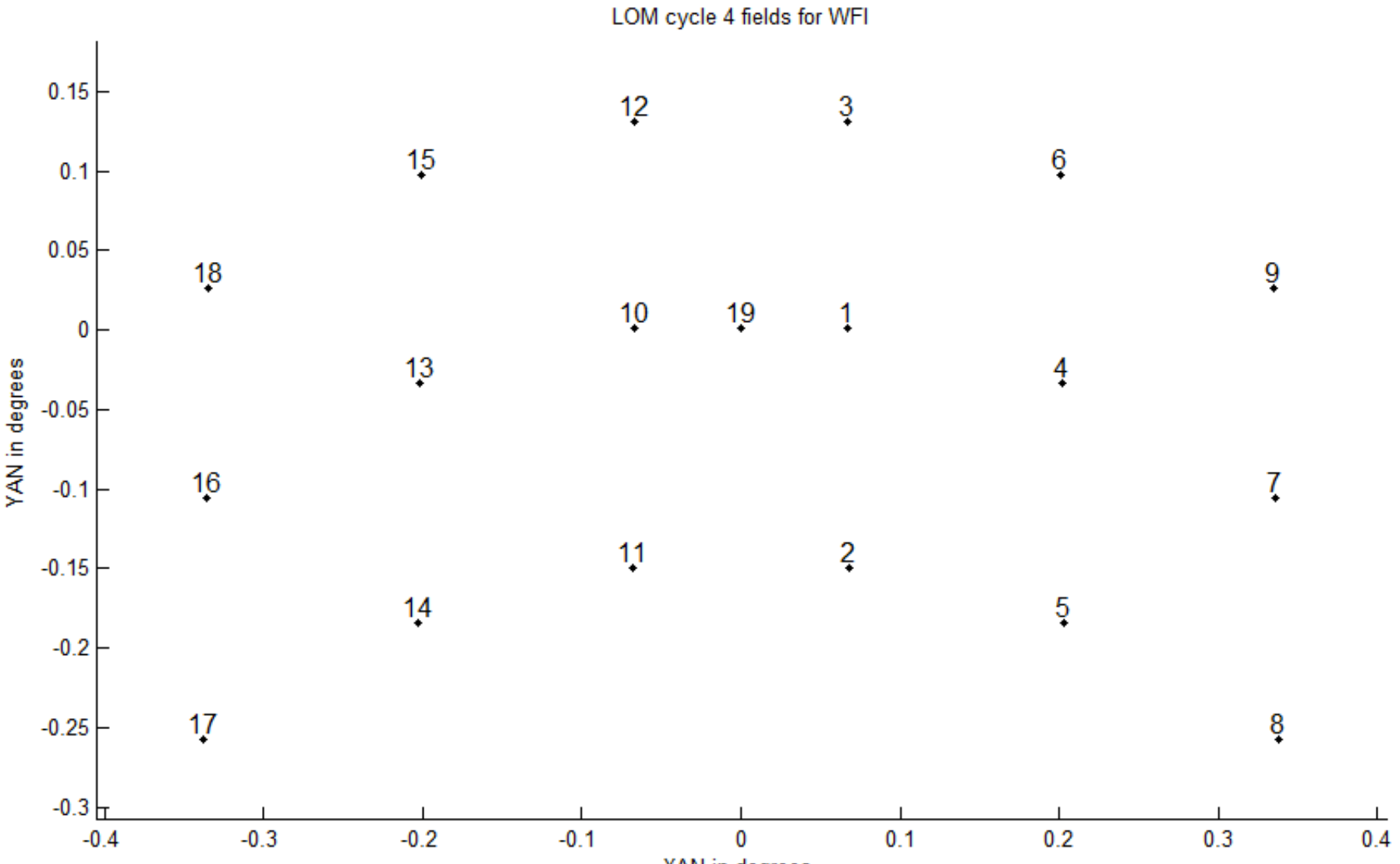
*For powered surfaces only

WIM Cooldown and Refocus Takeaways

- Wavefront error after Cooldown is dominated by ***power***
- On orbit adjustment of T2 and F2 in despace only allows for near-optimal system performance (close to the baseline)
- WIM mirror mount athermalization techniques in Cycle 4 greatly improved T2/F2 on-orbit refocus capabilities (RMS after refocus for Cycle 4 = 48nm; RMS after refocus for Cycle 3 = 300nm!)
  - M3 mirror mount in Cycle 4 does not yet incorporate the latest mounting technique … the 29.6 nm RMS surface sag noted on the previous page is now <10 nm.

BACKUP

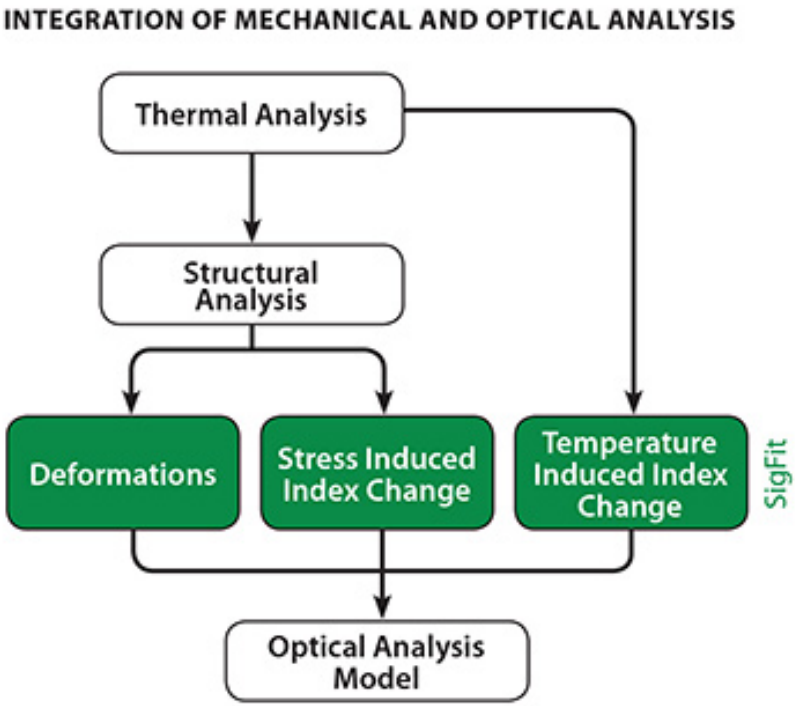
Widefield Channel FPA Field Points (one per SCA, and #19 FPA Center)



What is SigFit?

http://sigmadyne.com/sigfit-software/

"SigFit allows optomechanical engineers to integrate mechanical analysis with optical analysis. This allows calculations of optical performance predictions that include the effect of mechanical disturbances while leveraging finite element and optical analysis software already familiar to the user."



Sigfit can use a variety of polynomials to fit to a deformed optical element surface (or perform surface sag interpolation for higher accuracy) in order to generate a new optical element representation that can be input to actual optical analysis codes (e.g. Zemax, OSLO, Code V) to assess optical performance.